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METHOD AND COST OF MINING HARD SPECULAR HEMATITE ON THE MARQUETTE RANGE, MICHIGAN

BY

LUCIEN EATON

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METHOD AND COST OF MINING HARD SPECULAR HEMATITE ON THE MARQUETTE RANGE, MICHIGAN [1]

By Lucien Eaton[2]

INTRODUCTION

The mining methods described in this paper are those used in a large mine producing hard specular ore on the Marquette Range in the Upper Peninsula of Michigan. Although the conditions of mining are unique in this district, they are similar to those in many other districts, and information in regard to the methods used and the results obtained should be of interest. The methods now used are an outgrowth of those of former years which have been adapted to conform with improvements in mechanical appliances, changes in the wage scale and labor supply, and the selling price of the product.

The mine is situated at Ishpeming, in the Upper Peninsula of Michigan, 16 miles west of Marquette, its shipping port on Lake Superior.

ACKNOWLEDGMENTS

For much of the information in regard to the early history of the mine the author is indebted to Mr. James E. Jopling, of Marquette, Mich., who has been a mining engineer in the district for over 45 years. Information has also been taken from reports of the U.S. Geological Survey and the Geological Survey of Michigan, from publications of the Lake Superior Mining Institute, and from articles written by the author for the Explosives Engineer and the Engineering and Mining Journal.

HISTORY OF THE DISTRICT

Ore was first discovered on the Marquette Range in September, 1844, by United States surveyors who were making township surveys of the region. The first commercial body of ore was found by Marji Gesick, a chief of the Chippewa tribe of Indians, who showed it to explorers in September, 1845. This discovery was made on what was later the property of the Jackson Iron Co., in the city of Negaunee. In 1850 a large outcrop of ore was discovered in Ishpeming about 2 miles

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west of the original discovery. The ore in the mine to be described is an extension of this outcrop, but the fact was unknown for many years. The ore for which the mine was opened was discovered by diamond-drilling nearly 30 years after the outcrop was found.

The first shaft was begun in 1880, and another shaft, 800 feet farther west, was begun in the following year. Both shafts were dropped through quicksand. The second shaft was lost; after it had lain idle for about two years, however, it was recovered by the use of cast-iron tubbing and was straightened and sunk to the ore. With the exception of the years 1893 to 1897 and 13 months in 1921 and 1922 the mine has operated continuously. The total production has been approximately 10,000,000 tons.

Both shafts are vertical, and the ore was hoisted for many years on cages, but in 1910 the cages were superseded by skips of much larger capacity.

GEOLOGY

The ore occurs in the Upper Marquette Series of the Huronian Period, and is overlain by the Ishpeming quartzite and slate, with a footwall of jasper and altered diorite. It occurs as an irregular bed, badly folded and faulted, varying in thickness from a few feet to 100 feet, with an average thickness of 25 to 30 feet in the larger ore bodies (figs. 1 and 2). There is an unconformity between the ore and the hanging wall and probably in many places between the ore and the footwall, although the latter is not easy to determine.

In general the ore occurs in a syncline with an axis running east and west. This axis is not straight but pitches downward to the east and to the west from a high point near the middle of the ore body. Both sides of the syncline are present only near the middle as one side or the other has been removed by erosion or displaced by faulting in the other parts of the mine. Three major longitudinal faults have been recognized, and several minor longitudinal and cross faults are known to exist. The dip of the ore is irregular and in general is too low for the ore to run on the footwall by gravity. This fact and the occurrence of many interbedded seams of rock in the ore have had an important influence on the choice of the method of mining.

The ore formation is overlain by quicksand from 50 to 100 feet deep, and the ore bodies have been followed for long distances under the business portion of the town where the surface rights are not owned by the mining company. For these reasons it is necessary to use a method of mining that does not involve disturbance of the surface.

PHYSICAL CHARACTERISTICS OF ORE AND ENCLOSING ROCKS

The ore is a hard, specular hematite low in silica and moisture and containing appreciable amounts of lime and magnesia. The iron content is high, about 59 per cent natural, the phosphorus content is 0.100 per cent, and the silica is 5 to 7 per cent. It is separated into two grades, "lump" and "crushed." The physical structure, low moisture, and low silica content make the lump ore especially desirable for the open-hearth furnace.

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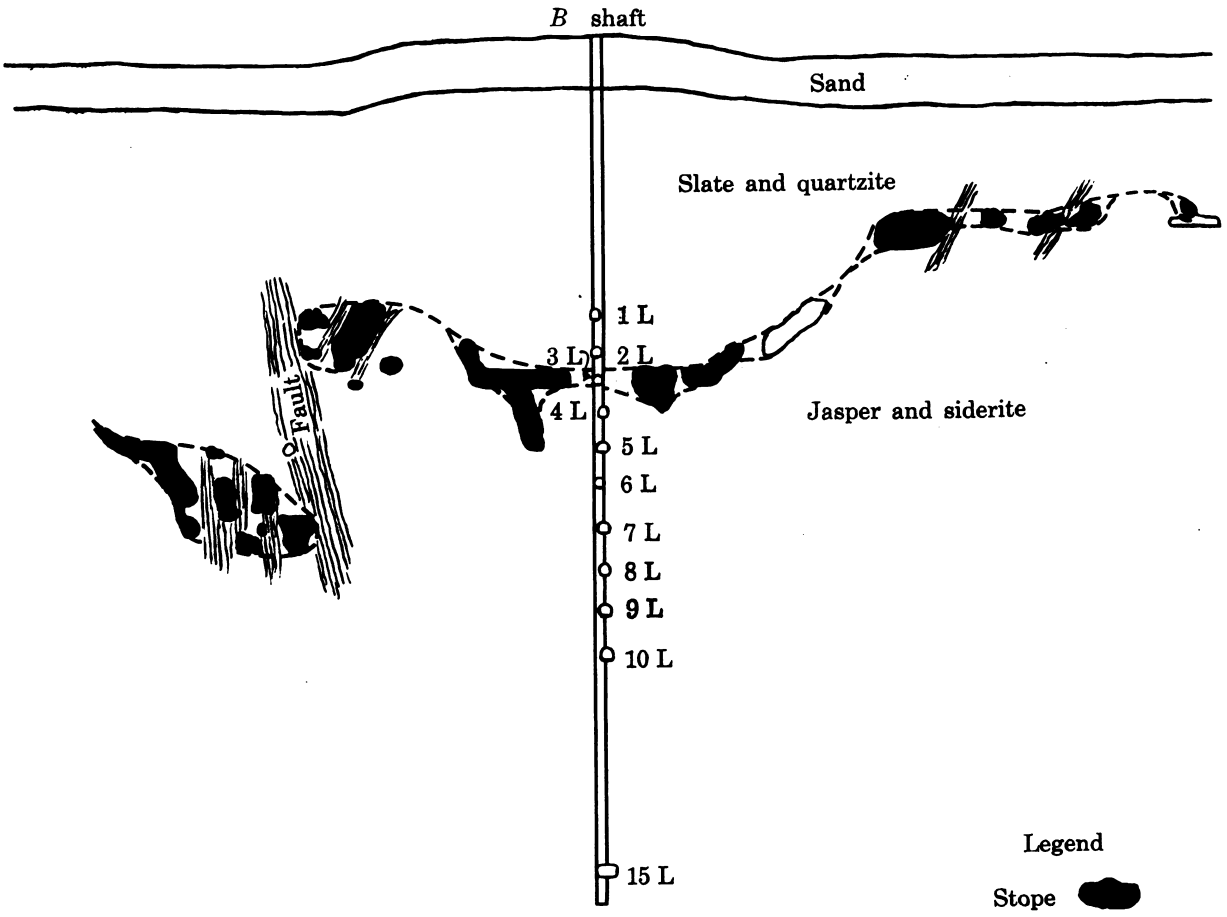

Figure 1. - North - south cross section through shaft, looking east

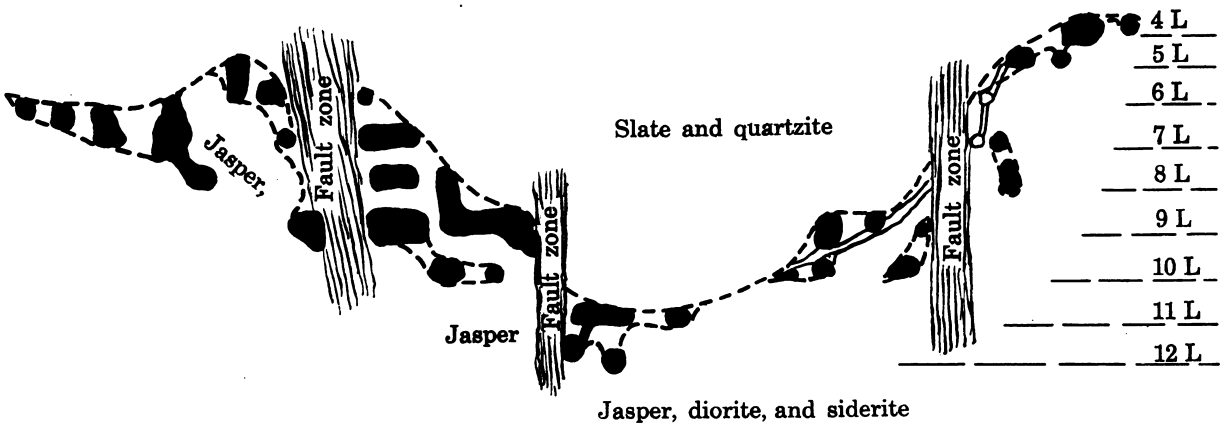

Figure 2. - North - south cross section 2,100 east

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The ore is tough and hard to drill, and it stands well on exposure to the air. Seams of rock from 1 or 2 inches up to 1 or 2 feet in thickness often occur in the ore and must be sorted out by hand underground. This fact and the flat dip of many of the ore bodies have made the use of shrinkage stopes impracticable, and a system of open rooms and pillars, with the ultimate recovery of many of the floors, has been found to meet the situation admirably.

The hanging wall in most places is a slate which slacks when exposed to the air; for this reason a small amount of ore is left to protect it wherever possible. Overlying the slate, which is seldom over 15 feet thick and usually much less, there is a strong, hard quartzite which does not weather or swell when exposed to the air, and which forms an excellent capping for the stopes in the system of mining employed. Under the slate in some places there is a conglomerate of jasper and ore.

The footwall is jasper or altered diorite. The jasper stands well under all conditions, but the altered diorite occasionally gives trouble, especially where it lies at a steep angle or has been sheared by faulting.

The displacement of the ore bodies by faulting and their irregular size and occurrence have rendered prospecting difficult and have made it impossible to block out large bodies of ore for mining. Great flexibility in the method of mining is required, and the ability to follow the ore wherever it goes is essential. These two conditions, as well as the inadvisability of caving the surface and the necessity of sorting out waste rock underground, have been determining points in the choice of a mining method.

In many parts of the mine, where there has been a good deal of faulting, a small amount of magnetite has been formed in the hematite mass; this has seriously interfered with the orientation of local strikes and dips and has complicated the study of the geology, especially of the many systems of joint planes.

SHIPPING FACILITIES

The mine is situated 16 miles from Lake Superior and is served by three railroads. Most of the ore is shipped by rail to Marquette and thence by water to Lake Erie ports, but a substantial tonnage is shipped entirely by rail to Canada and to the Chicago and St. Louis districts. The demand of customers for lump ore of high quality and of limited size has had an important bearing on the choice of mining method and on the treatment of the ore on surface.

METHODS OF PROSPECTING AND EXPLORATION

The earliest exploration was by vertical diamond-drill holes from the surface; a great deal of ore has been discovered in this way. In later years the underground workings standing open have become very extensive, so that it is now more economical and more effective to explore by horizontal diamond-drill holes underground. One diamond drill is kept in use nearly all the time, and averages over 2,000 feet of hole per year. Over 400 holes have been drilled underground during the life of the mine.

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Drilling is done with a screw-feed drill driven by compressed air, using "E" rods. Two men are required underground and part of a diamond-setter's time is needed on the surface. As the mine is piped with air and water for the rock drills, there is little difficulty in making a set-up anywhere.

A large part of the exploration is by drifts and raises, and the ore bodies are usually developed by breast stopes and raises. The old rule of following the ore is a very valuable one in this mine.

METHODS OF SAMPLING AND ESTIMATING TONNAGE AND VALUES

Production samples are checked by samples taken at intervals from the stopes and drifts and by the appearance of the ore. Only one grade of ore is hoisted, so that the sampling is a simple matter.

The standard methods adopted by the mining companies of the Lake Superior region and by the Lake Erie chemists are used to sample the product on the surface. These methods are fully described in the "Methods of the Chemists of the U.S. Steel Corporation for Sampling and Analysis of Iron and Manganese Ores," third edition, from which pertinent extracts are published in the 1927 edition of Crowell and Murray's "Iron Ores of Lake Superior."

Estimating the tonnage of ore available in the mine is an intricate and arduous task. With a few exceptions the ore bodies are most irregular, and their outline is not fully known until a large part has been extracted. The ore bodies on each level are carefully mapped, and the amount of available ore is calculated as closely as possible. The gross tonnage is also calculated, and the difference between the gross tonnage, the sum of the available ore, and the ore already extracted is the amount left to support the surface. The different pillars and floors are numbered, and a record is kept on special maps which are brought up to date once a year by subtracting the ore mined from and adding the new ore developed to the figures for the previous years. This system is practically a continuous inventory. It is checked by recalculations every few years.

In calculating developed tonnage allowances of 10 per cent for incidental rock and 10 per cent for loss in mining (in this case mostly ore left to protect the hanging-wall slate and in the rounded corners of the arches of the rooms) are deducted from the gross amount.

The analysis of the ore in the different parts of the mine is estimated from composite stope samples for each year and from the results of diamond-drilling allowance is made for contamination by incidental rock.

Values are calculated according to the formula of the Lake Superior Iron Ore Association. These calculations are too intricate to be included here, but may be found in the 1927 edition of Crowell and Murray's "Iron Ores of Lake Superior," page 107 et seq. At the present time a base ore (51½ per cent iron natural) of non-Bessemer grade is worth $3.25 a ton at the mine. For specific ores the price fluctuates according to analysis.

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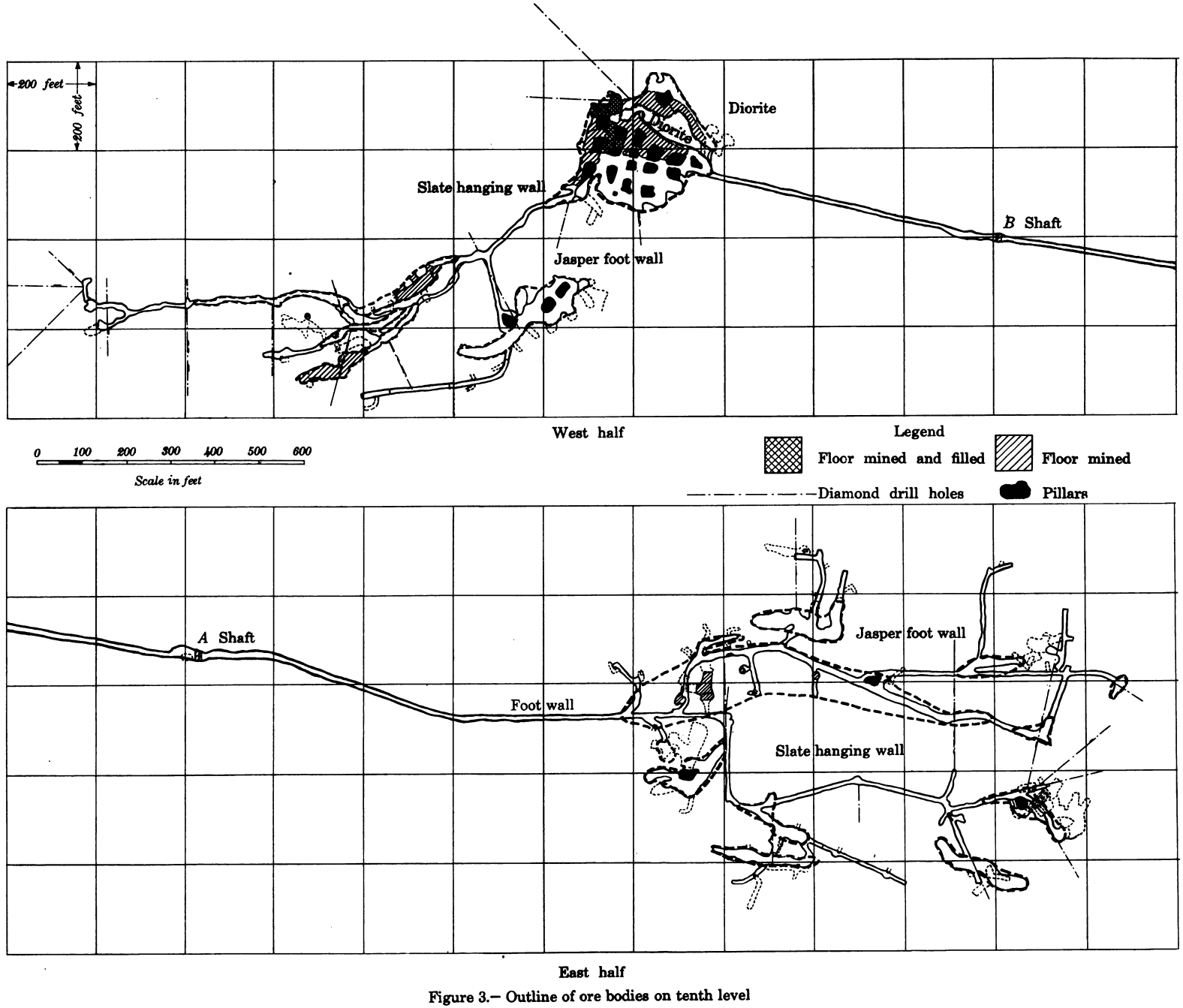

Figure 3.– Outline of ore bodies on tenth level

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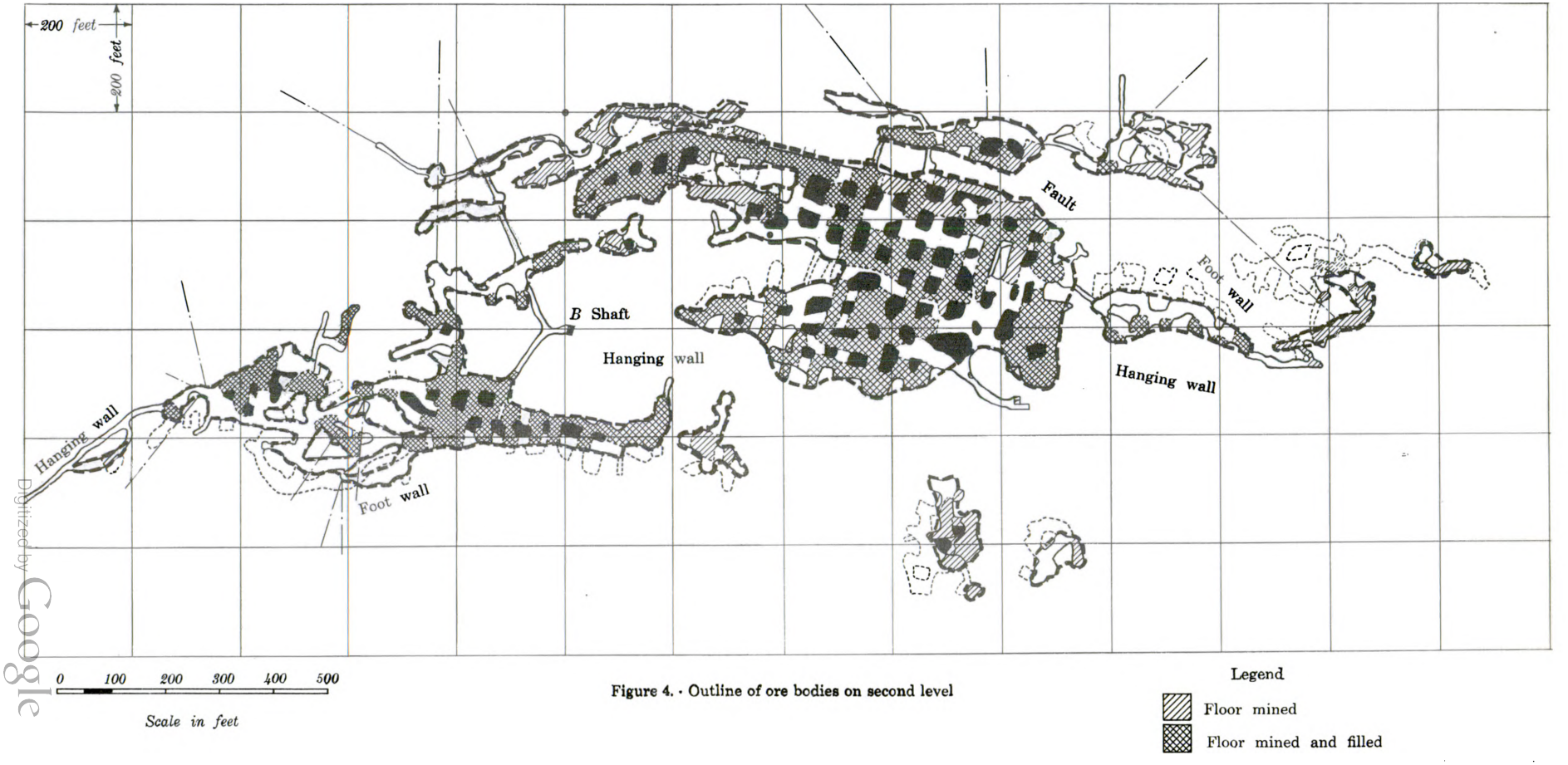

Figure 4. · Outline of ore bodies on second level

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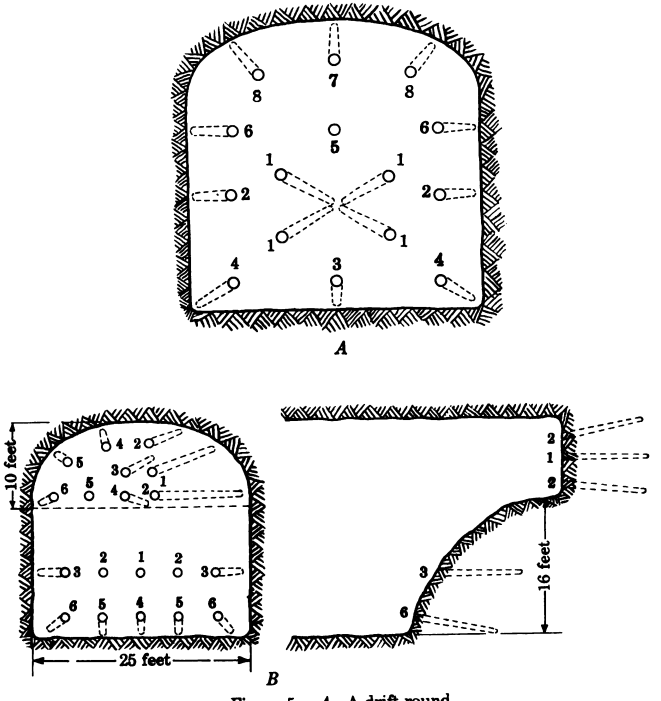

Figure 5.— *A*, A drift round.
B, A breast stope round

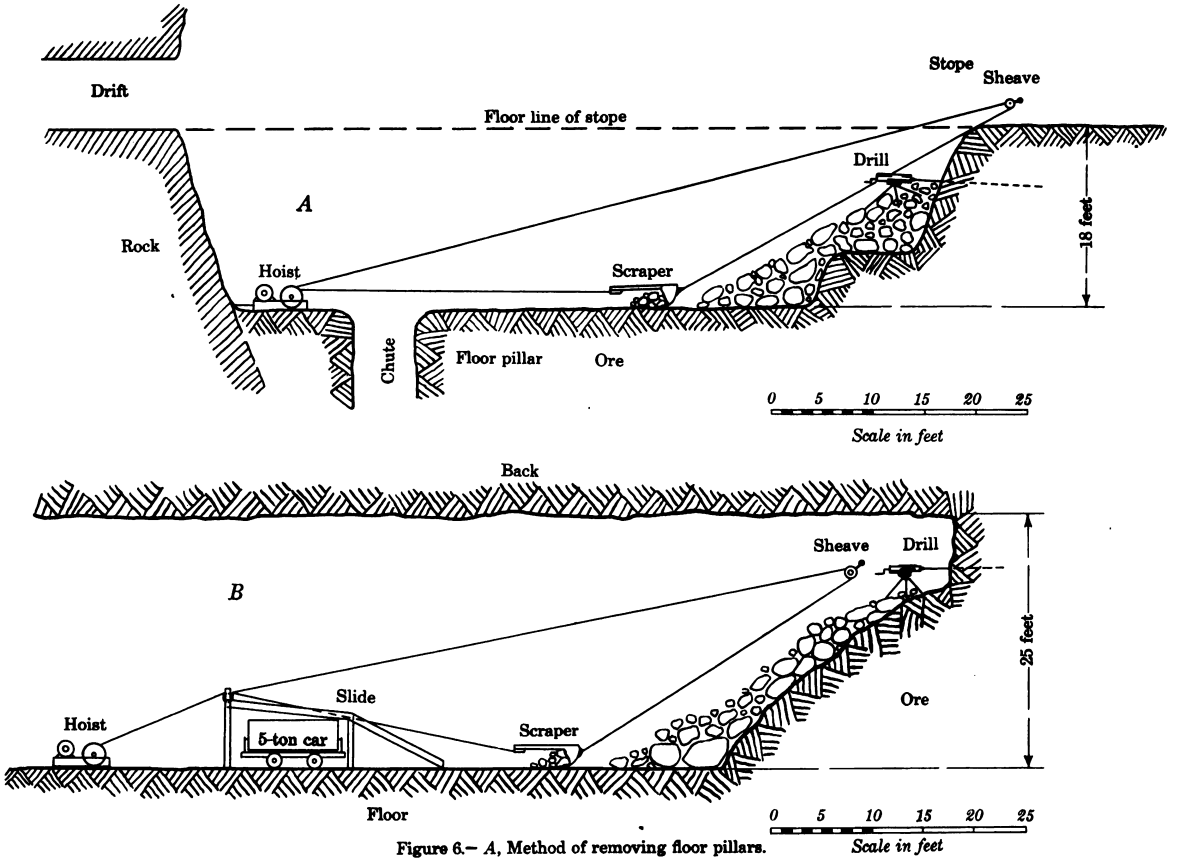

Figure 6.— *A*, Method of removing floor pillars.
B, Method of breast stoping

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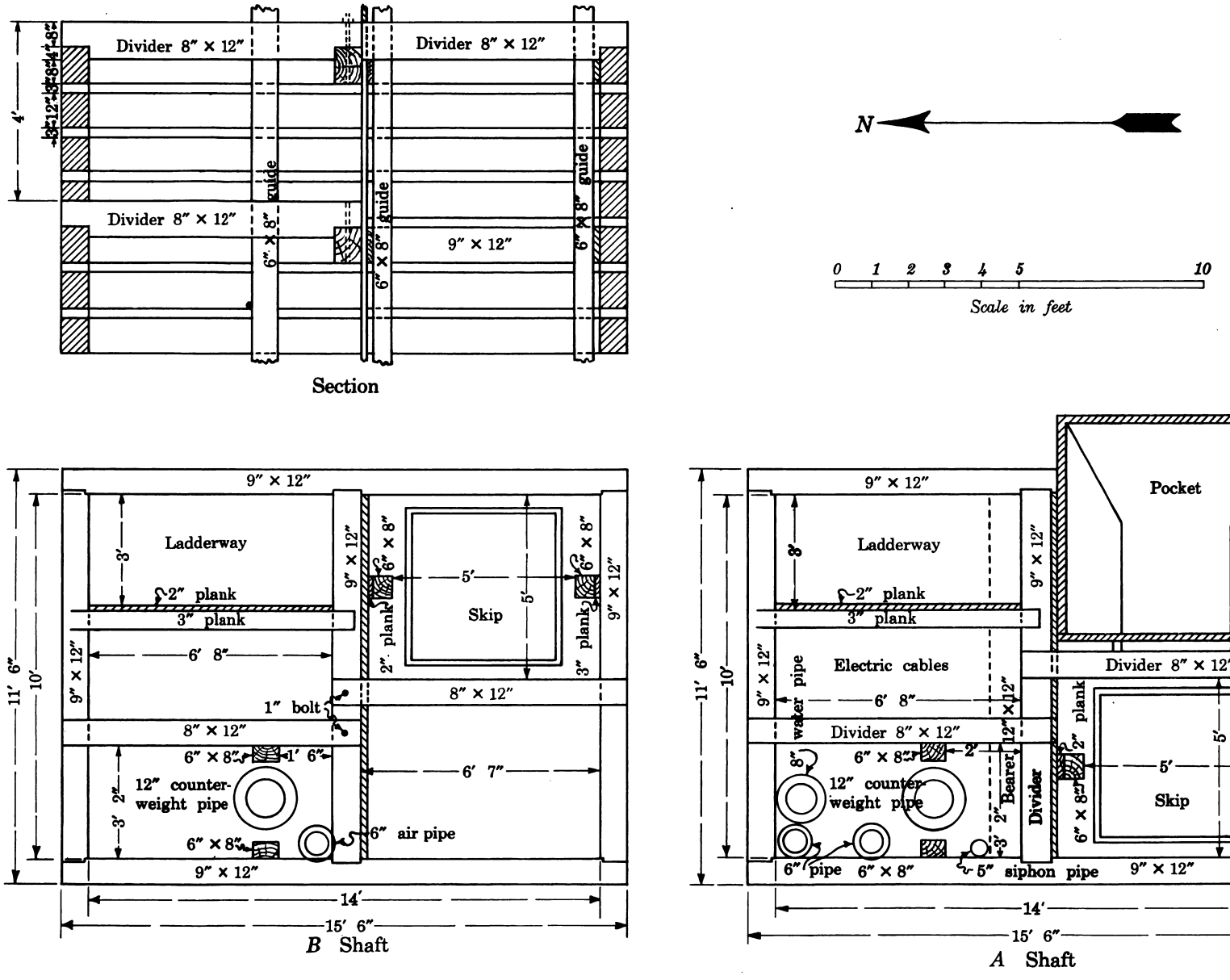

Figure 7. – Shaft arrangement

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DEVELOPMENT

Shafts.- The mine is opened by two shafts, "A" and "B", 820 feet apart. The shafts, which are vertical, are 1,060 feet deep, and their bottom levels are 1,000 feet from surface. They are similar in design, 10 by 14 feet inside of timbers, and are close-timbered for 750 feet. In the last 310 feet, sets were placed on 5-foot centers in the usual way, but this was found to be a mistake, as the ore that was spilled from the skips cut the wall plates away, and inside lagging had to be put in. There are 15 levels. The first level is at 340 feet from surface; the intervals between the next four levels are 40 feet each, but below the fifth level the interval is 50 feet. The levels between the tenth and fifteenth, however, are not connected directly with the shafts, and all the ore below the tenth level is transferred to the fifteenth level by means of chutes.

Figure 3 and figure 4 show the outline of the ore bodies and the development on two levels of the mine.

The shafts originally had two compartments, each 6 feet 8 inches by 10 feet. One compartment was for the cage and the other for the Cornish pump, pipes, and ladders. In 1910 the arrangement was changed by substituting a 5-ton skip for the cage and by adding a counterweight. The skip road was moved to one end of the cage compartment, and a pocket was built at the other end on every active level (fig. 7).

On account of the hardness of the ore and the large chunks handled, the skip is very heavily constructed and weighs approximately 10,000 pounds. It is provided with safety catches, and has a small platform on top of the bail, and has a bonnet on the rope for the protection of men when riding. The skip is overbalanced by a 6½-ton counterweight which travels inside a 12-inch pipe in the ladder and pipe compartment of the shaft. The counterweight consists of cast-iron cylinders, 11½ inches in diameter and 5 feet long, strung on a 3-inch wrought-iron eyebolt 31 feet long. It is free to turn in the pipe.

Drifts and Crosscuts.- Except in the slate and diorite the ground in the mine is very hard, and nowhere is timbering necessary for the support of drifts and crosscuts. Practically the only timber used in the mine is that in the shafts, chutes, and ladder roads. The older drifts were driven 7 feet high and 7 feet wide, but the standard drift is now 8 feet high and 8 feet wide. On main levels where trolley locomotives are used wider spaces are excavated every 100 feet for safety zones.

The usual round drilled has the cut above the center, and two cuts are taken out before the bench is blasted out. This is gradually being changed to a center-cut round, which is squared up at the same time that the cut is blasted. In drifting, 60 per cent gelatin dynamite in 1½ by 8 inch sticks is used, and the holes are fired by caps and fuses.

A typical round is shown in Figure 5A.

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The numbers show the order in which the holes are fired.

The drilling and blasting are done on the day shift, and the broken rock is loaded and hoisted at night. All waste rock is dumped underground and is used as filling.

Drills of the Water-Leyner type, mounted on 3-inch single-screw bars 7½ feet long, are used entirely in drifting. In very hard drifts, or in those in which rapid progress is desired, two machines are used on one bar. In other drifts one machine only is used. There is one miner for each machine.

The new drills used are of several makes and the latest models; all are 3½-inch machines weighing approximately 150 pounds. All machines use anvil-block chucks and 1¼-inch hexagon hollow drill-steel. Double taper cross bits with 105° cutting edges are used, the gauge changing three-thirty-seconds inch for every foot of length. Sizes are arranged so that a 10-foot steel will drill a 1 5/8-inch hole.

Compressed air is delivered at a minimum pressure of 75 pounds per square inch at the drill, and water at 50 to 75 pounds per square inch. The average air consumption is 75 cubic feet per minute per machine, including line loss, at peak load.

Loading is done nearly all by hand. A dipper-type loader has been used successfully, but as it requires that the air-compressor be run at night it is not economical, because loading and hoisting of rock is the only work carried on at night. Experiments with a scraper-loader mounted on wheels and driven by electricity have been very successful and more of these machines will be used in future; loading was done at the rate of 20 tons an hour.

Drifting is done by contract, the miners being paid by the foot. They are charged for explosives, carbide, and hand tools, but drill machines and accessories, steel and compressed air are furnished without charge. Shoveling and tramming the rock is charged against the cost of drifting, but is not included in the contract.

In softer ground it is possible to drill and blast a round once a shift, but in hard ground this is accomplished only twice or three times a week.

Raises.- Raises are 6 by 6 feet in cross section. They are usually driven at an inclination of 45 to 55°, but the majority are inclined at the steeper angle. A short pyramidal cut similar to that used in drifting is generally used. In hard ground a 3½-inch drifting machine mounted on a short 3-inch bar, the same used in drifting, is employed; but in the softer ground a dry stoper, using seven-eights-inch quarter octagon solid steel is preferred.

No timber is used in the raises, and the miners work standing on stages made of 2-inch plank resting on drill-steel. Chain ladders, made of three-fourths inch round iron, hung from iron pins driven into short drill holes are used for the men to climb on. These are left in the raise during blasting, and are often bent and sometimes broken, but in general they serve their purpose well.

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Stoping

Mining is done by means of open stopes with pillar support. A large percentage of the floors between the pillars is recovered, but no attempt is made to recover the pillars themselves, as the ore is overlain by quicksand and much of the mine under the city.

Where the thickness of the ore will permit, rooms 25 feet wide and 25 feet high are driven by breast stoping, and floors 25 feet thick are left between levels. On the upper levels the floors are only 15 feet thick.

The rooms are advanced by breast stoping (figs. 5B and 6B). A cut 7 or 8 feet high and as wide as the stope is driven 10 feet ahead of the bench, which is taken up afterward by lifting holes drilled horizontally. The cut is driven by slabbing holes, and advantage is taken of slips wherever possible. The success of the method depends largely on keeping the corners ahead and properly squared up. When the cut is far enough ahead, the breast is drilled again but not blasted, and the broken ore is cleaned off the bench. Lifting holes 8 to 10 feet deep are drilled 5 or 6 feet apart in horizontal rows with a burden of approximately 5 feet. The whole breast is then blasted at one time. As the bottom holes do not reach in as far as those above, a toe is left as a start for a new bench, and the broken ore lies on this toe in a pile high enough to allow the miner to reach the back at the breast conveniently. The back and breast are then trimmed, and drilling for the next cut is started. This method has many advantages. It facilitates trimming the back, always leaves a bench or a pile of broken ore for the miners to stand on, and provides a fairly continuous supply of broken ore for the trammers. It also gives a good opportunity for picking out rock before it has been discolored by the ore. As there are many seams of slate in the ore: this is very important.

When the ore in a breast stope does not extend up to the next level, it must be mined by back-stoping. In starting this operation a stage is built with ladders and 3-inch planks, and from it as many holes are drilled as possible. These holes are charged, the stage is taken down, and the holes are fired. The stage is erected again, more holes are drilled, and the operation is repeated until the pile of broken ore is high enough for the miners to reach the back without the stage. The stope is carried up to the top of the ore, and is then advanced longitudinally over the stope below. The ore is broken down by horizontal holes drilled in rows; these holes can often carry a 6-foot burden. At this stage the trammers usually start at the other end of the pile of broken ore, and tram it out as the stope advances, always leaving enough ore for the miners to stand on.

Extracting Floor Pillars.- In mining floors, present practice is to work on a sublevel instead of mining the entire 25 feet and dropping the ore to the level below (fig. 6A). In starting, a raise is put up, a chute erected, and the ore around the raise is milled into it by underhand work down to a depth of 18 feet. When the ore will no longer run into the chute by gravity, it is shoveled by hand and later dragged by scrapers. The scrapers are particularly effective in this work because the footwall is often so flat that the ore would

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have to be rehandled several times if it were shoveled by hand. Raises are usually about 100 feet apart, as the scrapers can easily reach 50 feet in either direction from the chute. When the ore has all been mined down to the floor of the sublevel, the remaining 7 feet can be mined in one lift and dropped to the level below.

Breast stopes (fig. 5B) are advanced by driving a 7-foot cut along the top of the breast for the full width of the stope. The holes are 7 to 8 feet deep, for which 50 per cent extra-low-freezing ammonia dynamite constitutes the charge. When a heading has been sufficiently advanced, it and the lower bench are carried ahead by simultaneous blasts. The same kind of machines and steel are used for drilling as in drifting, but the machine is mounted on a light tripod without weights instead of on a bar.

About five hours of drilling is done per shift; the machines drill from 5 to 6 feet per hour and average about 25 to 30 feet per shift. In full-sized stopes the burden is approximately 1 ton per foot of hole, and is less in the breast holes and more in the bench holes.

In the majority of cases one miner works in a stope, but occasionally there are two miners using two machines. The miners are paid by contract according to the number of cars (2.5 tons) trammed from the stope; the size of the stope, the hardness and toughness of the ore, etc., are taken into account in setting the price. Contracts are charged with all explosives, carbide, picks, shovels, and other hand tools, but are not charged for compressed air, or for drills and drill steel.

The ore breaks in large pieces, so that a good deal of sledging and secondary blasting is required. The largest pieces are blockholed for blasting, and the flatter pieces are bulldozed. This work is done by the miner as part of his contract.

Distribution of Drill Steel.- Each contract has its own steel, stamped on the shank with numerals one-half inch high, and receives each day the same steel sharpened that it sent up dulled the day before.

The sharpened steel is sorted after being tempered and is made up in bundles of 100 to 125 pounds, held together by hardwood wedges in a welded iron ring $4\frac{1}{2}$ inches in diameter. The wedges and rings are used over and over again, but one new wedge is used in each bundle, and on that wedge the contract number is written with blue chalk. The dulled steel is not sorted. Sharp steel is delivered by the cage-riders at the proper levels, and is carried to the working places by the miners. Dull steel is handled by the same men, but in the reverse order.

The average consumption of drill steel in 1928 was .105 pound per ton of ore and rock produced.

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Loading Ore in Stopes

By hand.- In stopes where there is much rock to sort out, and in stopes the life of which will be short, it is better to load the ore by hand than mechanically.

The standard car is made entirely of steel, is of the end-dump type with the body rigidly fastened to the truck, and is equipped with 14-inch roller-bearing wheels. The car stands 37½ inches high, weighs 1,400 pounds empty and 7,000 pounds loaded, and carries a load of 5,600 pounds or 2½ tons; it has a capacity of 37 cubic feet. The track is 24-inch gauge and is laid with 20-pound rails.

In most places the tram is short, and the car is dumped into a chute by means of a cradle. Where the tram is long the trammers are supplied with a 1½-ton storage-battery locomotive.

The trammers (loaders or shovelers) work in pairs on contract; they are paid a certain price for filling the car and 1 cent for every 45 feet trammed. When a locomotive is provided, only the filling price is paid. The contract basis is as follows:

Price per car (2½ tons)

	Large piles	Stopes	Drifts	Chutes
Hand-filling	$0.47	$0.52	$0.57	- -
Chute filling	- -	- -	- -	$0.20
Tramming (per 45 ft.)	.01	.01	.01	.01
Minimum from chute	- -	- -	- -	.28
Minimum by hand	.55	.60	.65	- -

Note:- Prices are about 10 per cent higher for wet places. Prices for filling vary with the type of chute.

Loading by Scrapers into Chutes.- On sublevels and where a chute is within reach the broken ore is moved from the breast to the chute by scrapers (fig. 6A). These scrapers are all of one design, 48 inches wide and 7 feet long, of the hoe type, and weigh 1,500 pounds. The blade, side-plates, and draw-head are made of manganese steel. The blade is the only part that wears appreciably, and this has a life of 6,000 to 10,000 tons, averaging about 8,000 tons.

The scraper is hauled by a 25 hp. double-drum electric hoist, with planetary transmission, using five-eighths-inch extra plow-steel wire rope with independent wire-rope center (fig. 9). The motor is 25 hp., 900 r.p.m., 440 v.a.c., 3 phase, 60 cycle, of squirrel-cage type. A complete scraping outfit, exclusive of electric cable, costs $1,150 set up in place.

One miner and one scraperman constitute the crew in a stope.

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The scraperman helps the miner in setting up and tearing down his machine, and the miner helps the scraperman rig up his scraper-blocks. The miner is paid by the car trammed from the chute and in most places the scraperman is paid by the day. This system is gradually being changed to a contract basis for both men.

Contract prices per car (2½ tons) dumped in the chute vary from 90 cents to $1.50, including both breaking and scraping.

Loading Cars with Scrapers.- In a few places semiportable steel scraper-slides are used to fill main haulage cars (fig. 6B). The scraper slides are not mounted on wheels, and must be taken apart to be moved. The hoist is not mounted on the slide, but is set up at one side of the track, and the ropes pass through blocks hung from the back or from the framework of the slide. Both hoist and scraper are of the same type as used in the stopes, previously described, and the crew in the stope is also the same - one miner and one scraperman.

Main-line cars stand 56 inches high and hold 76 cubic feet (5½ tons). Exclusive of switching, the time required to load a car is six minutes. Including delays and switching, four cars (22 tons) are loaded in an hour.

The number of places using this equipment is being increased.

The slide weighs 3,660 pounds and costs $360.

Underground Transportation

Trolley locomotives and large cars are used on three levels - the eighth, tenth, and fifteenth. On most of the other levels storage-battery locomotives are used with 2.5-ton end-dump cars. There are six trolley locomotives and 11 storage-battery locomotives in the mine.

The storage-battery locomotives vary in weight from 1½ to 4 tons. They are all 24-inch gauge, and all but two are equipped with Edison A4 cells.

The trolley locomotives are all 6½-ton, 250-volt, double-motor machines. The track is 30-inch gauge, laid with 40 pound rails.

The cars are of rocker-dump design and hold 76 cubic feet (5.5 tons) of ore (fig. 10). Both locomotives and cars are equipped with automatic couplers. These cars are pulled to the shaft in trains of five or six, and the loaded cars are left at the shaft to be spotted by a tugger hoist, while the locomotive returns "inside" with a train of empties. An automatic switch turns the empties onto a siding as soon as the cars are dumped, in order to leave the main line clear for the next train of loads. No uncoupling is necessary except at the locomotive.

The cars are dumped one at a time into the shaft pocket, which has a capacity of only one car and acts merely as a chute through which the contents of the car are discharged into the skip. The loading time is 10 to 12 seconds.

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No skip-tenders are employed; the cars are dumped by two skip-riders who go from level to level dumping the loaded cars that have been left on the sidings. The wages of these men is charged to tramming.

The standard chute in use underground is the Alaska-Treadwell finger chute slightly improved (fig. 8). For 20 feet above the chute the raise is put up at an angle of 45°, and is then turned to right or left or upward, so that the velocity of the ore in falling will be checked by the elbow thus formed. The chute itself is made of 3-inch hemlock plank and is lined with three-eighths-inch boiler plate. Chute fingers are made of 4 by 6-inch fir dressed on all sides to $3\frac{1}{2}$ by $5\frac{1}{2}$ inch, and are painted before being taken underground. The strap forming the hinge at the top is of three-eighths by 4-inch soft steel, and the wearing shoe at the lower end of the short member is a manganese-steel casting. The apron to catch the dribblings that pass through the fingers is made of steel. As all sizes are standardized throughout the mine, the various parts can be made up in the mine shops in quantity at considerable reduction in cost.

After a raise has been worn smooth, the time of loading at the chute is short; a $2\frac{1}{2}$-ton car can be loaded in 15 to 20 seconds and a 5-ton car in less than half a minute. The efficiency of these chutes has been a large factor in maintaining a large production.

PERCENTAGE OF EXTRACTION

One of the characteristics of the room-and-pillar method of mining is that a large percentage of the ore reserves is left in the mine as floors. While the breast stopes are advancing, floors on the line of haulage can not be mined unless provision is made to transfer the ore to lower levels. The extraction in wide bodies is approximately 65 per cent, but in narrow ore bodies with strong walls standing nearly vertical it may be as high as 90 per cent. The average for the mine has been 72 per cent.

The percentage of extraction can be worked out very closely by a checker-board system, determining the percentage of ore mined in the stopes and pillars and also in the floors, and combining the percentages. The results check very closely with actual production.

VENTILATION

Only natural ventilation is needed. The downcast is through an adjoining idle mine, with which there is a connection from the eighth level in shaft A, and the upcast is through both the hoisting shafts. With a little care there is practically no trouble in distributing the fresh air to all parts of the mine.

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FIRE HAZARDS

Although both the shafts are wet and there is very little timber in the mine, neverthe less a complete system of fire doors has been established, so that the incoming air can be instantly cut off and the flow of air between the two shafts can be instantly stopped by merely turning compressed air into the pipe line leading to the door latches. On each level at the shaft, in each headframe on the surface, and at the downcast airway there is a valve for this purpose.

First-aid and fire-helmet crews receive regular monthly training from the company's central organization and from the Bureau of Mines Mine Rescue car when it visits the district.

TABLE 1.- SUMMARY OF COSTS

Number of mine: - No. 1. Period covered: Year of 1928.

Long tons ore hoisted during period: 420,000.

Mining method: Open Stopes with pillar support.

Underground Costs Per Long Ton of Ore Hoisted

	Labor	Super-vision	Compressed air, drills, and steel	Power	Explosives	Timber	Other supplies	Total
Development:								
In ore	$ .027	$ .004	$ .015	- -	$ .009	$ .003	$ .009	$ .067
In rock	.080	.009	.030	- -	.022	.003	.007	.151
Mining	.514	.028	.104	$ .006	.105	.002	.011	.770
Transportation. (underground)	.142	.007	- -	.042	- -	.005	.048	.244
General underground. expense	.075	.007	.004	.060	- -	- -	.034	.180
Total	$.838	$ .055	$ .153	$ .108	$ .136	$ .013	$ .109	$1.412

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TABLE 2.- SUMMARY OF COSTS IN UNITS OF LABOR, POWER, AND SUPPLIES

Number of mine: No. 1. Period covered: Year of 1928.

Long tons ore mined and hoisted: 420,000.

Mining method: Open rooms with pillar support.

	Development	Mining	Total
A. Labor (Man hours per long ton):			
Breaking (drilling and blasting)	.112	.342	.454
Timbering and filling	.022	.051	.073
Mucking	.060	.310	.370
Haulage and hoisting	.017	.220	.237
General	.032	.096	.128
Supervision	.014	.037	.051
Total labor underground	.257	1.056	1.313
Average tons per man per shift	- -	- -	6.10
Labor, percentage of total cost	- -	- -	65.
B. Power and Supplies:			
Explosives (lbs. per long ton)	.196	.705	.901
(Kind and grade)	60% l.f. ammonia	50% l.f. ammonia	- -
Timber (b.m.)	.221	.224	.445
Power (kw.h. per long ton):			
Air compression	- -	4.33	- -
Hoisting	- -	2.04	- -
Pumping	- -	4.02	- -
Scrapers and lights	- -	.41	- -
Haulage and lights	- -	.76	- -
Total		11.56	
C. Percentage of Total Cost:	15.4	84.6	100.0

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TABLE 2.- DETAIL OF COSTS IN UNITS OF LABOR, POWER, AND SUPPLIES

	Drifting	Raising
Size of excavation	8 by 8 feet	6 by 6 feet
Timbered or not	Not	Chutes only
Physical properties of rock and ore	Hard	Hard

	Total Development
A. Labor (Man Hours per Foot):	
Breaking	7.11
Timbering	1.40
Mucking	3.81
Haulage and hoisting	1.08
Supervision	.81
Total labor	14.21
Feet per man-shift of 8 hours	0.5634
B. Power and Supplies per Foot:	
Explosives (lbs. per ft.)	12.5
Timber (bd. ft.)	13.4
Total power (kw.h.)	62
C. Percentage of Total Cost:	
Labor	62%
Supplies	38%

* * * * * *

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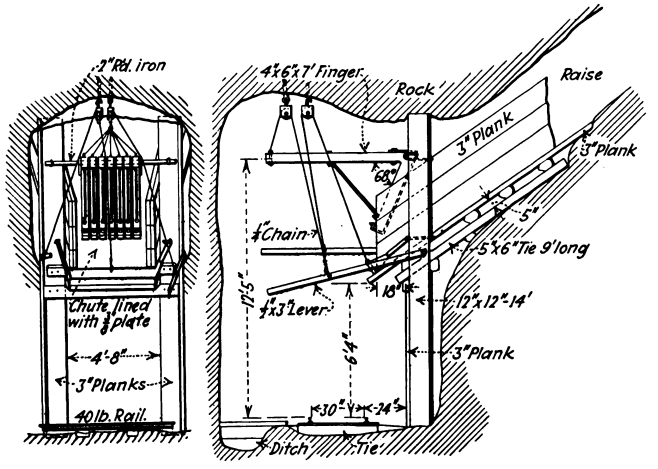

Figure 8.— Design of improved Alaska Treadwell finger chute adopted as standard

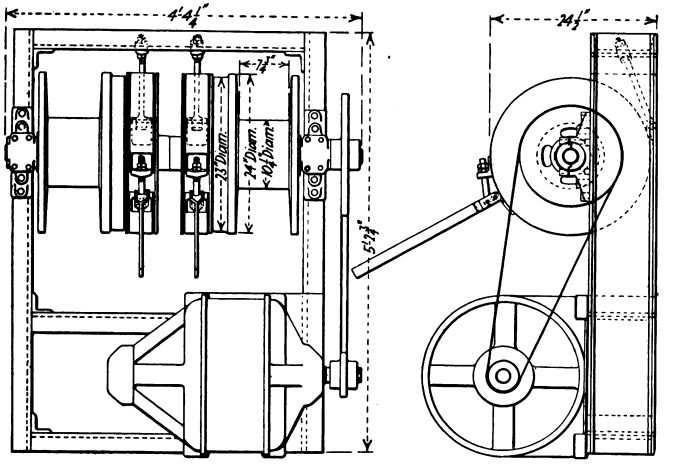

Figure 9.— Design of planetary scraper hoist

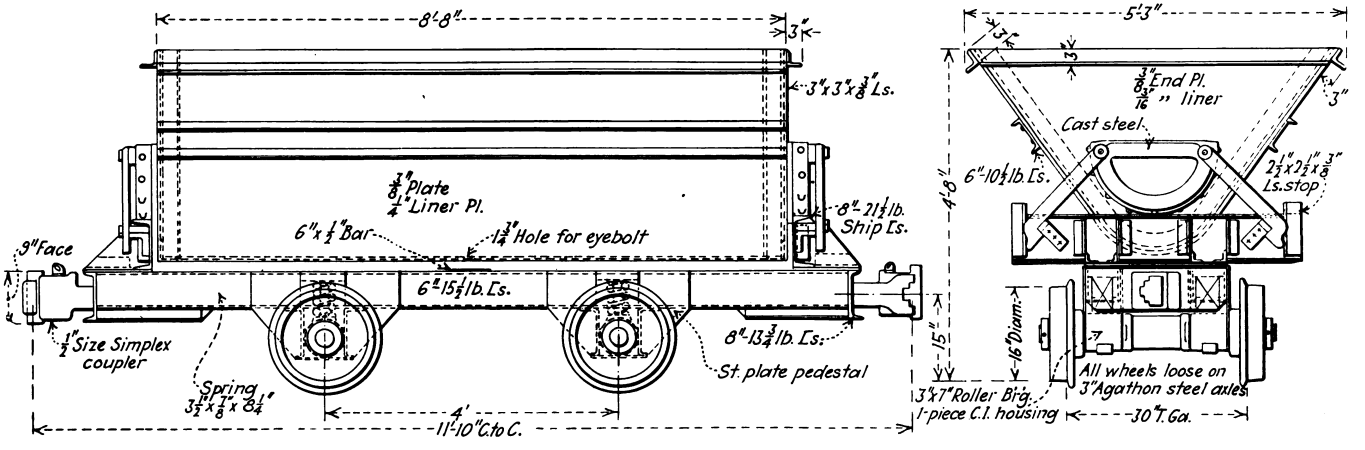

Figure 10.— Sketch of 76-cubic-feet rocker-dump ore car used on main-line tracks

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